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A NOTE ON THE ORIGIN OF THE D-LAYER

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ABSTRACT The origin of D-layer of the upper atmospheres is here considered to be due to the settling of dust-like metallic particles of meteoric origin on the inversion level at 55-60 kilometres. The inversion of temperature with its consequent over-stability is considered to be due to the heating of the atmosphere by high-speed meteors that come to earth continuously from space. With this idea a number of optical and electrical phenomena found associated with this layer is tried to be accounted for. Lastly it is also found that the potentiality of this layer for radio fade-outs discovered by Dellinger can be well explained by such a hypothesis.

The mechanism of formation of the three important stratification of the upper atmospheres, the E- and the F-ionisation layers and of the low-lying ozone layer, except for the details, is by now, more or less, correctly understood mainly from the contributions of Lenard,[1] Pennekoek,[2] Chapman,[3] Saha[4] and Mitra.[5] Lately another layer intermediate between the low ozone layer and the well-known E-layer has been discovered.[6] This layer is generally known as D-layer. The height at which it is found to exist is between 55 and 60 km. The existence of such a layer of stratification at such low heights is difficult to account for on any theory, but it appears to be confirmed by the discovery of the phenomenon of radio fade-outs that are observed to occur on the sun-lit parts of the earth's atmosphere practically simultaneous with the appearance of intensely luminous patches on the face of the sun.[7] It is found that the layer of temporary "ionospheric winds" responsible for the above fade-outs exists also at a height below that of E-layer at about 55-60 km, practically same as that of the D layer.[8]

The cause of such a layer of stratification at about that height is as yet uncertain. And in the absence of any definite theory about its origin it is vaguely assumed[9] that it is caused as a reaction to the process of continuous formation and dissociation of ozone molecules which is going on in the upper atmosphere. Recently Prof. S. K. Mitra and Dr. J. N. Bhar and Mr. S. P. Ghosh have dealt with the problem of the formation of this layer.[10] They are of opinion that the D-layer is formed by the photo-ionisation of O_2 at its first ionisation potential. But the main difficulty with this layer is that its existence is not a continuous one. Moreover, there should exist in it a potentiality to develop itself suddenly to the particular state that is responsible for the phenomenon of radio fade-outs.

The ozone hypothesis about the cause of this D-layer is untenable for various reasons, the most significant of which is the fact that perhaps the entire ozone of the upper atmospheres is confined between 15 and 40 kilometres as recently established by Götz, Dobson and Meetham and others,[11] with a maximum concentration at about 23 kilometres.[12] And along with this, if one takes into account that the total vertical amount of ozone is hardly 2 mm. in thickness (N.T.P) at the equator and 2·5 mm. in high latitudes (northern),[13] one fails to understand how this can effect the formation of a layer that can so strongly influence the passage of radio waves.

A very significant fact about the stratifications in the upper atmospheres is that they are also the positions where the law of normal vertical temperature distributon is disobeyed. Just at the lower base of the ozone layer the normal vertical temperature distribution comes to a standstill for some height and, after that, instead of a fall there is actually a rise with height. Similarly in the case of E- and F-layers they are also the seats of raising of temperature of atmospheres at those levels. The temperature of the E-layer is taken to be about 300°K and of the F_2-layer sometimes as high a figure as 1000°C is ascribed.[14] Had the ordinary law of vertical distribution of temperature been satisfied, the temperatures of these layers would have been much different.

If one looks at these stratifications from this direction one can immediately see that they can very well be interpreted as cases of temperature inversions. As is well-known in Dynamical Meteorology, all temperature inversions cause layers of atmospheres to deviate to greater stability and can, in this way, act against the forces of gravity in stopping heavier particles to have their natural fall. But the stability of these layers (ozone, E and F), as now interpreted, is not primarily due to the forces of inversion.

In the case of D-layer, on the other hand, it can be said to possess properties of temperature inversion. At about 65 km. height the temperature of the atmosphere is found to be as high as 380° Absolute, from the investigations of Lindemann and Dobson[15] and those of Öpik[16] on meteors and that of Pekeris[17] on atmospheric oscillations. Just beyond the ozone layers at about 40 km. there is a tendency of the atmosphere to cool down. The layer of atmosphere in between the two limits of 50 km. and 60 km. is subjected to the forces of inversion and thus assumes a state of permanency that in its turn becomes strong enough to resist the forces of mixing which exist both above and below.

The cause of the heating of the atmosphere between 60 and 80 km. do not introduce any difficulty. This part of the upper atmosphere is continually subjected to the bombardment of innumerable meteoric particles from space. The kinetic energy of these meteors is partly used to disrupt the particles into their constituent molecules and is partly absorbed by the atmosphere through which they happen to pass. From the average number of meteors entering the Earth's atmosphere per sec., from an estimate of their average mass and the constituent and also remembering that the average velocity of these meteoric particles is something like 20 kilometres per second, the rate at which the energy is absorbed by the layer can be estimated. Assuming that the atmosphere is essentially composed of N_2 and O_2 molecules in their normal proportions even at this height the rate of heating can be calculated. After allowing for the loss by radiation to both upper and lower layers the temperature at which the layer attains an equilibrium temperature can be estimated. This is found to be about 450° Absolute at about 65 kilometres height, in turn creating a level of temperature inversion at a height of about 55 kilometres.

The heavy meteoric particles now reduced to metallic dust try to settle down and come to the surface of the earth, but the inversion at 55 kilometre level stops them to fall further. They temporarily settle themselves at this level, and continue on accumulating till they overcome the forces of inversion, when there occurs a collapse of this metallic layer. After a collapse again another accumulation continues on. This may be the reason why the D-layer is only detected strongly at times and practically undetectable at others.

This layer being made up of particles chiefly of iron and silicon and perhaps also of sodium produces various effects upon a number of terrestrial phenomena. It is not possible to deal with them adequately in a note like this. A full discussion will appear in the main paper. Yet one or two points may be mentioned here. The spectrum of the night sky shows a fluorescence of continuous background superposed on which lie the bands of nitrogen molecule and metastable oxygen atoms. Elvey and Roach[18] have proved that this fluorescent background lies at a height of 50-65 kilometres. The layer being a metallic one can very well account for a continuous emission.

Recently the lines of atomic sodium are detected in the night-sky spectrum by Cabannes and his co-workers.[19] They place this sodium in the upper atmospheres at a height of 130 km., whereas Bernard[20] suggests that the sodium D light is emitted from a thin layer at about 60 km. Assuming that the layer of inversion is also a seat of heavy particles to accumulate, it can be asserted that the level of sodium should begin somewhere at this height. This receives a support from the observation that at sunset when the sun's rays rise past this level, the D-light intensity falls within a minute or two to about 1 per cent. of its former value.[21]

The theories of terrestrial magnetism demand a conducting layer at a certain height in the upper atmospheres. This layer of metallic particles, perhaps chiefly of iron, satisfies very well the demand. I have as yet not considered the subject in any detail. But I hope to discuss the effect of a mantle of iron particles round the earth on terrestrial magnetism in a separate contribution.

I have already referred to the phenomenon of solar eruptions and its associated effect of radio fade-outs, which is caused in this D-layer round the sub-solar point. It has been found that all the solar eruptions cannot impart the particular characteristics to this layer responsible for the fade-out effects. Considering all the points I am very much tempted to suggest that if iron line can be detected in emission during such an eruption and if a spectro-heliogram can be taken of the sun with this line, there may be found a one-to-one correspondence between the two phenomena.

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